


310088914-092002  
JC02 Rec'd PCT/PTO 25 MAR 2002

FORM PTO 1390 (REV 5-93)		US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY DOCKET NUMBER 2002-0417A
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. §371			U.S. APPLICATION NO. (if known, use 7 CFR 1.5) [NEW] <b>10/088914</b>
International Application No. PCT/NO00/00302	International Filing Date September 15, 2000	Priority Date Claimed September 24, 1999	
Title of Invention EMULSIFIED GELANT			
Applicant(s) For DO/EO/US Arne STAVLAND; Svante NILSSON			
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:			
1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. §371. 2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. §371. 3. <input checked="" type="checkbox"/> This express request to begin national examination procedures (35 U.S.C. §371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. §371(b) and PCT Articles 22 and 39(1). 4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date. 5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. §371(c)(2)) a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau). b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau. c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US) 6. <input checked="" type="checkbox"/> A translation of the International Application into English (35 U.S.C. §371(c)(2)). <b>ATTACHMENT A</b> 7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3)). a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau). b. <input type="checkbox"/> have been transmitted by the International Bureau. c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has <b>NOT</b> expired. d. <input type="checkbox"/> have not been made and will not be made. 8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19. 9. <input checked="" type="checkbox"/> An <b>unexecuted</b> oath or declaration of the inventor(s) (35 U.S.C. §371(c)(4)). <b>ATTACHMENT B</b> 10. <input checked="" type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. §371(c)(5)). <b>ATTACHMENT C</b> <b>Items 11. to 14. below concern other document(s) or information included:</b> 11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98. <b>ATTACHMENT D</b> 12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 13. <input checked="" type="checkbox"/> A <b>FIRST</b> preliminary amendment. <b>ATTACHMENT E</b> <input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment. 14. <input checked="" type="checkbox"/> Other items or information: a. Cover Page of Published International Application No. WO01/21726 - <b>ATTACHMENT F</b> b. International Search Report - <b>ATTACHMENT G</b>			

U.S. APPLICATION NO. <b>107-088914</b> [NEW]		INTERNATIONAL APPLICATION NO. PCT/NO00/00302		ATTORNEY'S DOCKET NO. 2002-0417A					
15. [X] The following fees are submitted  <b>BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):</b> Neither international preliminary examination fee nor international search fee paid to USPTO and International Search Report not prepared by the EPO or JPO ..... \$1040.00 International Search Report has been prepared by the EPO or JPO ..... \$ 890.00 International preliminary examination fee not paid to USPTO but international search paid to USPTO ..... \$ 740.00 International preliminary examination fee paid to USPTO but claims did not satisfy provisions of PCT Article 33(1)-(4) ..... \$ 690.00 International preliminary examination fee paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) ..... \$ 100.00  <b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>				<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 50%;">CALCULATIONS</th> <th style="width: 50%;">PTO USE ONLY</th> </tr> <tr> <td colspan="2" style="height: 100px;"></td> </tr> </table>		CALCULATIONS	PTO USE ONLY		
CALCULATIONS	PTO USE ONLY								
Surcharge of \$130.00 for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).									
Claims	Number Filed	Number Extra	Rate						
Total Claims	38 -20 =	18	X \$18.00	\$ 324.00					
Independent Claims	2 - 3 =	0	X \$84.00						
Multiple dependent claim(s) (if applicable)			+ \$280.00	\$1,364.00					
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$1,364.00					
[X] Small Entity Status is hereby asserted. Above fees are reduced by 1/2.				\$ 682.00					
<b>SUBTOTAL =</b>				\$ 682.00					
Processing fee of \$130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				+					
<b>TOTAL NATIONAL FEE =</b>				\$ 682.00					
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40 per property				+					
<b>TOTAL FEES ENCLOSED =</b>				\$ 682.00					
				Amount to be refunded	\$ -				
				Amount to be charged	\$				
a. [X] A check in the amount of \$ <u>682.00</u> to cover the above fees is enclosed. A duplicate copy of this form is enclosed. b. [ ] Please charge my Deposit Account No. 23-0975 in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed. c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>23-0975</u> .									
<b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b))          must be filed and granted to restore the application to pending status.</b>									
19. CORRESPONDENCE ADDRESS  <div style="text-align: center;">   <b>000513</b>          PATENT TRADEMARK OFFICE       </div>			By: <u>Matthew Jacob</u> Matthew Jacob, Registration No. 25,154  WENDEROTH, LIND & PONACK, L.L.P. 2033 "K" Street, N.W., Suite 800 Washington, D.C. 20006-1021 Phone: (202) 721-8200 Fax: (202) 721-8250  <div style="text-align: right;">March 25, 2002</div>						


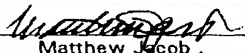
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U.S. APPLICATION NO. <b>10988914</b> [NEW]		INTERNATIONAL APPLICATION NO. PCT/NO00/00302		ATTORNEY'S DOCKET NO. 2002-0417A			
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19. CORRESPONDENCE ADDRESS   <b>000513</b> PATENT TRADEMARK OFFICE				By:  Matthew Jacob, Registration No. 25,154  WENDEROTH, LIND & PONACK, L.L.P. 2033 "K" Street, N.W., Suite 800 Washington, D.C. 20006-1021 Phone: (202) 721-8200 Fax: (202) 721-8250  March 25, 2002			

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[2002-0417A]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of :  
Arne STAVLAND et al. : Attn: BOX PCT  
Serial No. [NEW] : Docket No. 2002-0417A  
Filed March 25, 2002 :  
EMULSIFIED GELANT : THE COMMISSIONER IS AUTHORIZED  
[Corresponding to PCT/NO00/00302 TO CHARGE ANY DEFICIENCY IN THE  
Filed September 15, 2000] FEE FOR THIS PAPER TO DEPOSIT  
ACCOUNT NO. 23-0975.

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents,  
Washington, DC 20231

Sir:

In the interest of reducing PTO filing fees, please amend the present application as follows:

IN THE CLAIMS:

*Please cancel claims 1 to 30 without prejudice to the subject matter thereof and add the following new claims in their place:*

31. (New) A composition for reducing water permeability more than oil permeability in a subterranean reservoir, which composition comprises an aqueous gelant emulsified in oil.

32. (New) The composition according to claim 31, wherein the gelant concentration in the emulsion is in the range up to 50 volume%.

ATTACHMENT E

33. (New) The composition according to claim 32, wherein the gelant concentration is above 5 volume%.
34. (New) The composition according to claim 31, wherein the gelant comprises water soluble polymers.
35. (New) The composition according to claim 34, wherein the polymers are polyacrylamides, polyacrylate copolymers or biopolymers.
36. (New) The composition according to claim 31, wherein the polymer concentration in the gelant is present in a concentration sufficient to give a stable gel after cross-linking.
37. (New) The composition according to claim 36, wherein the concentration is from 1,000 to 50,000 ppm.
38. (New) The composition according to claim 37, wherein the concentration is from 2,000 to 10,000 ppm.
39. (New) The composition according to claim 31, wherein the gelant comprises one or several cross-linking agents.
40. (New) The composition according to claim 39, wherein the cross-linking agent is hexamethylenetetramine and/or salicyl alcohol and/or trivalent metal ions.
41. (New) The composition according to claim 40, wherein the trivalent metal ions are chromium or aluminum.

42. (New) The composition according to claim 39, wherein one or several cross-linking agents is present in a concentration range of from 50 to 5,000 ppm.

43. (New) The composition according to claim 42, wherein the concentration is from 100 to 1,000 ppm.

44. (New) The composition according to claim 31, wherein the emulsion is stabilized by a surfactant.

45. (New) The composition according to claim 44, wherein the surfactant is an oil soluble surfactant.

46. (New) The composition according to claim 31, wherein the surfactant is present in a concentration of from 0.05 to 10%.

47. (New) The composition according to claim 46, wherein the surfactant is present in a concentration of from 0.1 to 2%.

48. (New) The composition according to claim 31, wherein the emulsion breaks in 1 to 15 hours at a temperature of from 50 to 130°C.

49. (New) The composition according to claim 48, wherein a gel is formed after the emulsion breaks.

50. (New) A process for reducing water permeability more than the oil permeability in a subterranean reservoir wherein an aqueous gelant emulsified in oil is injected into a reservoir.

52. (New) The process according to claim 51, wherein the gelant concentration in the emulsion is above 5 volume%.

53. (New) The process according to claim 49, wherein the gelant emulsified in oil comprises water soluble polymers.

54. (New) The process according to claim 53, wherein the water soluble polymer is a polyacrylamide, polyacrylate copolymer or biopolymer.

55. (New) The process according to claim 50, wherein the polymer concentration in the gelant emulsified in oil is present in a concentration sufficient to give a stable gel after cross-linking.

56. (New) The process according to claim 55, wherein the polymer concentration in the gelant emulsified in oil is from 1,000 to 50,000 ppm.

57. (New) The process according to claim 56, wherein the concentration of the gelant emulsified in oil is in the range of from 2,000 to 10,000 ppm.

58. (New) The process according to claim 50, wherein the gelant comprises one or several cross-linking agents.

59. (New) The process according to claim 58, wherein the cross-linking agent is hexamethylenetetramine and/or salicyl alcohol, and/or trivalent metal ions.



60. (New) The process according to claim 59, wherein the trivalent metal ion is chromium or aluminum.
61. (New) The process according to claim 50 wherein one or several cross-linking agents are present in the range of from 50 to 5,000 ppm.
62. (New) The process according to claim 61, wherein one or several cross-linking agents are present in the range of from 100 to 1,000 ppm.
63. (New) The process according to claim 50, wherein the emulsion is stabilized by a surfactant.
64. (New) The process according to claim 63, wherein the surfactant is an oil soluble surfactant.
65. (New) The process according to claim 63, wherein the surfactant is present in a concentration range of from 0.05 to 10%.
66. (New) The process according to claim 65, wherein the concentration range is from 0.1 to 2%.
67. (New) The process according to claim 50, wherein the emulsion breaks in 1 to 15 hours at a temperature 50 to 130°C.
68. (New) The process according to claim 67, wherein the gel is formed before the emulsion breaks.

**REMARKS**

The claims are 31 to 68.


The above amendment presents a new set of claims based on the previous claims but without multiple dependency.

Further, the above amendment places the claims in better condition for examination.

Favorable action on the merits is now requested.

Respectfully submitted,

Arne STAVLAND et al.

By   
Matthew Jacob  
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March 25, 2002

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16 MAY 2002

10/088914

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Arne STAVLAND et al.

Serial No. 10/088,914

Filed March 25, 2002

EMULSIFIED GELANT

[Corresponding to PCT/NO00/00302

Filed September 15, 2000]

Attn: BOX PCT

Docket No. 2002-0417A

THE COMMISSIONER IS AUTHORIZED  
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FEE FOR THIS PAPER TO DEPOSIT  
ACCOUNT NO. 23-0975.

SECOND PRELIMINARY AMENDMENT

Assistant Commissioner for Patents,  
Washington, DC 20231

Sir:

In the interest of compact prosecution, please amend the present application as follows:

IN THE DRAWINGS:

Please enter attached Figures 1 through 12 as the drawings of this application.



WO 01/21726

1

PCT/NO00/00302

**Emulsified gelant**

The present invention comprises a composition and a process that reduces the water permeability in a subterranean reservoir more than the oil permeability using an emulsified gelant. Further, the present application comprises the use of a composition comprising an aqueous gelant emulsified in oil.

Gels are used in reservoirs to reduce the water cut while maintaining, or even increasing, the oil production from a well.

10

To obtain a simple and cost effective treatment the gelant should be placed by bullhead injection. In order not to impair the oil production, the gel must have some form of self-selectivity. One method is to use gels that reduces the permeability of water more than that of oil, so called disproportionate permeability reduction (DPR). The use of DPR-gels is limited to shut-off isolated water producing layers or to coning situations. (SPE 50983, Disproportionate Permeability reduction is Not a Panacea, Stavland et al. 1998.)

20

It was demonstrated in "Mechanistic Study of Disproportionate Permeability Reduction", SPE/DOE 39635 (Nilsson, S., Stavland, A. and Jonsbråten, H.C.) that the DPR effects is controlled by the core wettability and the gelant saturation in the core. The best DPR- effects have been found to occur in fractional wet media. To obtain a good DPR-effect, i.e. preserving the oil permeability and reduce the water permeability, it is important to preserve oil continuous channels. In homogeneous wetting media, oil continuous channels are easier to obtain in a oil wet media than in a water wet. In a water wet media aqueous gelants tend to block narrow passages and especially pore throats with the result that also small amounts of gel gives rise to strong permeability reductions for both phases.

25

Apart from the wettability of the core material, which is determined by the reservoir and cannot be changed much, another important parameter is the gelant volume fraction, which is comprised, in the present invention. Little can be done in practice with the wettability leaving the gelant saturation during placement as the operational variable. The volume fraction of the gel can be varied in two dif-

30

ferent methods. One method is direct injection of the gelant at residual oil saturation,  $S_{or}$ , so that the gelant occupies the entire aqueous volume and that the gel then shrinks by synerising water. Another possible method is to inject gelant together with oil. Coinjection of gelant and oil is found to be successful. The important parameter is the oil saturation in the core during placement. It is important to realise that the saturation in the core is a function of both the relative permeability curves and the oil/gelant ratio during placement. The saturation in the core is not the same as the saturation in the injected stream, which is a disadvantage for practical applications since reliable relative permeability curves are not always available. The disadvantage with coinjection is that it is easy to carry out in the laboratory, but very difficult to do in the field.

The present invention describes the mechanisms of DPR-gels and how DPR-gels can be optimised. Further on the present invention comprise DPR gels which reduce the permeability of water with little or no impact on the oil permeability. One important motivation for developing DPR gels is more simple and cost effective implementation, i.e., by bullhead injection, but it is important to optimise the use of DPR gel systems.

To optimise the DPR effect it is important to place the gel at oil saturation higher than the residual. The present invention comprises injection of a gelant as an emulsion dispersed in oil. When gelant is emulsified in oil, it can be treated and pumped as a pseudo one-component system. The emulsion should not be too stable and preferably break spontaneously within a couple of hours.

The present application comprises a composition and a process for reducing the water permeability more than the oil permeability in a subterranean reservoir, which composition comprises an aqueous gelant emulsified in oil. The gelant in the present invention comprises water soluble polymers, preferably polyacrylamides, polyacrylate copolymers or biopolymers which is present in a concentration sufficient to give a stable gel after crosslinking, usually in the concentration range of from 1000 to 50000 ppm, more preferably in the concentration range of from 2000 to 10000 ppm. The composition and process according to the invention also include one or several crosslinking agents which is hexamethylene-

tetramine and/or salicyl alcohol and/or trivalent metal ions preferably chromium or aluminium. The crosslinking agents is present in a concentration range of from 50-5000 ppm, preferably in a concentration range of from 100-1000 ppm. The emulsion of the present invention is stabilised by a surfactant, preferably an oil soluble surfactant, which is present in a concentration range of from 0.05 to 10%, preferably in the range of from 0.1 to 2%. The emulsion of the invention is not too stable and breaks in 1-15 hours at a temperature of from 50-130°C. The emulsion can be considered as a pseudo one-component system. Another important feature of the emulsion is that it breaks spontaneously before a gel is formed. The use of a composition comprising an aqueous gelant emulsified in oil for reducing the water permeability more than the oil permeability in a subterranean reservoir is also described in the present invention. The gelant concentration in the emulsion is in the range up to 50 volume%, preferably in the range of 5-50%, and the gelant emulsified in oil comprises water soluble polymers, preferably polyacrylamides, polyacrylate copolymers or biopolymers.

An emulsified gelant is prepared by taking a water based polymer and cross linker dissolved in brine. The gelant is then emulsified in oil with an added surfactant as emulsion stabiliser. An example of an emulsified gelant is as follows. The gelant used here was HE 300 /HMTA/salicylalcohol in Isopar oil added an oil soluble surfactant as emulsion stabiliser but any aqueous gelant could have been used. The emulsion breaks in a couple of hours at 90°C, and before gel is formed. The gel formed does not synerese. We are now able to tailoring the selectivity only by the gelant concentration in the oil.

Emulsified gelants has been found to be useful as DPR systems. The permeability reduction for both oil and water follows a simple, in fact almost linear, relation as a function of saturation in the core after placement. Emulsified systems are easier to handle and predict than the previously evaluated coinjection of oil and gelant. (Nilsson, S., Stavland, A. and Jonsbråten, H.C.: "Mechanistic Study of disproportionate Permeability Reduction", SPE/DOE 39635.

From the experimental result concerning the emulsified gelant systems, the emulsified gelants behave effectively as a pseudo one-component system. The

saturation in the core becomes approximately the same as the gelant content in the emulsion (figure 1). The efficiency of the emulsion in terms of selectivity is quite similar to the previously investigated coinjection of gelant and emulsion if the comparison is made in terms of residual resistance factors (figure 10).

5 The gelant saturation in the core and the gelant saturation in the emulsion are not exactly the same and the deviation has been in the range 1 – 12% units for the fractional wet cores. If emulsions could be considered as perfect pseudo one-component systems there should have been no deviations at all.

10 In water wet media the permeability reduction was much stronger, when using a gelant with the saturation of gelant in the oil (25%) since an aqueous gelant in a water wet media blocks narrow passages like pore throats. With the present invention it is important to notice that it is possible to obtain a measurable per-  
15 meability reduction instead of a complete blocking. The reason is that the oil (in the emulsion) helps to keep some channels open so that it is possible for oil to flow through the core without first having to break the gel mechanically.

20 An important difference between water wet and fractional wet media in the present application is that the saturation in the core after placement differed significantly from the saturation in the emulsion. The saturation in the water wet core after placement was 58% as compared to 25% in the emulsion. In fractional wet cores the difference is much less and about 1 – 12 %. This shows that the core material "traps" the wetting fluid.

25 Figure 1 shows saturation after placement in a fractional wet core as a function of % gelant in the injected emulsion.

30 Figures 2-9 shows relative permeability curves before and after gel treatment for oil and water.

Figures 10-12 shows residual resistance factor for oil as a function of residual resistance factor of water after gel treatment of fractional wet cores.



## Examples

### Experimental arrangement

- 5 The chemicals that have been used are:  
Synthetic seawater: the composition is as indicated in the table below

**Table 1.** Composition of synthetic sea water.

Salt	Conc. (g/litre)
NaCl	24.79
MgCl <sub>2</sub> · 6H <sub>2</sub> O	11.79
CaCl <sub>2</sub> · 2H <sub>2</sub> O	1.60
KCl	0.80
SrCl <sub>2</sub> · 6H <sub>2</sub> O	0.02
Na <sub>2</sub> SO <sub>4</sub>	4.14
NaHCO <sub>3</sub>	0.21

- 10 *Oil:* Isopar H, a high boiling alkane fraction produced by Exxon.

*Gelants:* Waterbased polymer with a corresponding crosslinker giving a suitable gelation time.

- 15 *Surfactant:* A surfactant has been used to stabilise the emulsified gelants in oil.

Flooding experiments in sand-packs were carried out in 2 cm diameter columns with a length of ca 30 cm. Coarse glass filters (por 1) were mounted at the inlet and outlet. The pressure ports on the columns were 25 cm apart and about 2.5  
20 cm from the ends. Two different types of sand have been used. Acid cleaned quartz sand, 50-75 µm particle size, which is water wetting, and Teflon powder which is oil wetting. The Teflon powder was delivered by Avocado Research Chemicals and was in the form of small granules with internal pores.

- 25 Two different system were used to pack the columns:

1. Mixture of quartz sand and Teflon powder, 50/50 by volume, referred to as fractional wet
2. Quartz sand only, referred to as water-wet

5

The cores thus obtained have well defined wettability properties, fractional wet and water-wet. The permeabilities was about 2000 mD before gel treatment and porosities about 45-55%. The permeabilities to brine (synthetic sea water) and oil before and after gel injection were measured at room temperature by the following procedure:

10

1. The column was first saturated by oil.
2. Water was injected at low flow rate, 0.5 ml/min, until no more oil was produced and the water saturation ( $S_w$ ) and permeability of water ( $k_w$ ) were measured.
3. The injection rate of water was increased step wise and  $S_w$  and  $k_w$  were measured at each step at steady state.
4. Oil was injected.  $S_w$  and the oil permeability ( $k_o$ ) were measured in the same way as above.
5. Gelant were injected until steady state was reached.
6. The cores were shut in for 3 days at 90°C.
7. The cores were taken out to room temperature and water was injected at low rate, 0.1 ml/min,  $S_w$  and water permeability after gel treatment ( $k_{w,gel}$ ) were measured, the injection rate of water was increased step wise and  $S_w$  and  $k_{w,gel}$  were measured at each step at steady state.
8. Oil was injected.  $S_w$  and oil permeability after gel treatment ( $k_{o,gel}$ ) were measured in the same way as above.

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9. Occasionally water was injected again and  $S_w$  and  $K_{w,gel}$  were measured as above to check for gel stability.

The residual resistance factors (RRF) and tables that are quoted in the present application are the ratios between the endpoint permeabilities taken before and after gel treatment.

The tables 4-10 demonstrate data which is common to all core floods at the following conditions:

Length between pressure ports 25.1 cm, dead volume 1.74 ml. Area 3.14 cm<sup>2</sup>, total length ca 30 cm, viscosity of water 1 cP and oil 1.15cP.

Units used in the table are psi for the pressure (DP), ml/min for the flow rate, produced volumes of oil and water in cumulative ml.

#### Example 1 - Emulsified gelant

In the work from 1997 of Nilsson, S., Stavland, A. and Jonsbråten, H.C.: "Mechanistic Study of Disproportionate Permeability Reduction", SPE/DOE 39635 it was found that useful DPR effects, i.e. preserving the oil permeability as much as possible and at the same time reduce the water permeability, could be obtained by coinjecting oil and gelant. The important parameter is the oil saturation in the core during placement. The purpose of this activity is to evaluate whether or not these problems can be circumvented by injecting the gelant as an emulsion. When gelant is emulsified in oil it can be treated and pumped as a pseudo one-component system.

A non-emulsified gelant, 100% gelant and no oil, is included as a comparison below.

Recipe and properties of emulsified gelant.

The gelant used in all the emulsion experiments was HE300 with HMTA and salicylalcohol. The concentration was 5000 ppm HE 300 with 1000 ppm HMTA

and 2000 ppm salicylalcohol added as crosslinker. The polymer solution was sheared in a Silverson mixer at 3/4 of maximum speed for 15 minutes.

The gelant (non-emulsified) was found to gel over night at 90°C. There was no  
5 gelation at room temperature within one month.

The emulsion was prepared by dispersing the gelant in Isopar and mixing with the Silverson mixer at 3/4 of maximum speed for 5 minutes.

An oil soluble surfactant, was used as an emulsion stabiliser and was found to  
10 be adequate, the surfactant concentration was 0.5% in the oil phase. An oil soluble surfactant was selected since these tend to favour oil continuous emulsions. Emulsion viscosity is about 10-20 cp depending on shear and gelant/oil ratio. The viscosity of the polymer solution alone was 10 cp.

15 The emulsion breaks in a couple of hours at 90°C. At room temperature the emulsion breaks partly and gentle stirring is needed to maintain the system as an emulsion. In bulk samples at 90°C the emulsion breaks before the gel has formed.

20 Core flood:

A series of core floods has been carried out using different gelant/oil ratios. The core material has been fractional wetting, quartz/Teflon in most of the core floods. In one of the core floods the packing material was water wet quartz. The  
25 results are summarised in tables 2 and figures 1-5. More detailed data on the core floods are given in experimental arrangement.

The emulsions could be injected in the cores without problem and behaved like a one-phase fluid with a viscosity of about 10 cP. The fluid was also produced as  
30 an emulsion at the outlet (after breakthrough). It was found that the saturation in the core became somewhat higher but still about the same as the saturation of the injected emulsion (figure 1). The emulsion system is thus a simple way to control the saturation during placement as compared to co-injection of oil and gelant where the relative permeability curves need to be considered. Since the

effluent was an emulsion the saturation after placement could not be obtained in the usual way from produced volumes of oil and water. Instead a chloride titration was carried out at the very end of the core floods and the saturation was then obtained by calculating backwards from the produced volumes.

5

With 15% gelant in the emulsion the result was a rather weak permeability reduction with an insignificant selectivity (figure 2). The water flooding after gelation was also stopped at an early stage since it looked as if small gel aggregates were produced from the core. The end point saturation for water may therefore  
10 be unrealistically low compared to the other floods. No such indications were observed in the floods with higher gelant contents in the emulsions.

If the gelant concentration in the emulsion is increased the result is a clear disproportionate permeability reduction where the selectivity increases as the overall permeability reduction increases. The highest gelant concentration used was  
15 50%, which resulted in a permeability reduction for water of 350 and a factor of 9.0 for oil. Intermediate gelant concentrations naturally produced intermediate permeability reductions, for instance 20% gelant gave  $RRF_w = 2.9$  and  $RRF_o = 1.6$ , in a repeat core flood with 20% gelant the result was  $RRF_w = 23$  and  $RRF_o = 3.5$ . The difference between the two experiments can be traced to the fact that  
20 the gelant saturation in the core was higher in the repeat experiment, see table 2 and figure 1.

As can be seen in table 2 the use of emulsified gelant gives a considerable protection of the oil permeability as compared to the use non-emulsified gelant  
25 (100%).

The relative permeability curves are given in figures 1-9.

30

**Table 2.** Summary on experimental result using emulsified gelant and fractional wet cores.

Gelant content in the emulsions and saturation after plament ( $S_w$ (gel))	Residual resistance factors	Selectivity $RR_w / RR_o$	Endpoint permeability for oil/endpoint saturation before and after gel treatment	Endpoint permeability for brine/endpoint saturation before and after gel treatment
15% gelant in emulsion, $S_w$ (gel) = 0.16	$RRF_w = 1.4$  $RRF_o = 1.3$	1.08	$k_o = 1745$ ( $S_w = 0.09$ )  $k_{o,g} = 1324$ ( $S_w = 0.17$ )	$k_w = 2120$ ( $S_w = 0.51$ )  $k_{w,g} = 1521$ ( $S_w = 0.46$ )
20% gelant in emulsion (1), $S_w$ (gel) = 0.23	$RRF_w = 2.89$  $RRF_o = 1.61$	1.80	$k_o = 2182$ ( $S_w = 0.06$ )  $k_{o,g} = 1351$ ( $S_w = 0.13$ )	$k_w = 2858$ ( $S_w = 0.50$ )  $k_{w,g} = 988$ ( $S_w = 0.54$ )
20% gelant in emulsion (2), $S_w$ (gel) = 0.32	$RRF_w = 23$  $RRF_o = 3.5$	6.6	$k_o = 1331$ ( $S_w = 0.06$ )  $k_{o,g} = 382$ ( $S_w = 0.23$ )	$k_w = 1725$ ( $S_w = 0.50$ )  $k_{w,g} = 75$ ( $S_w = 0.60$ )
25% gelant in emulsion, $S_w$ (gel) = 0.36	$RRF_w = 2.64$  $RRF_o = 1.80$	1.5	$k_o = 1512$ ( $S_w = 0.10$ )  $k_{o,g} = 842$ ( $S_w = 0.18$ )	$k_w = 1776$ ( $S_w = 0.49$ )  $k_{w,g} = 673$ ( $S_w = 0.56$ )
30% gelant in emulsion, $S_w$ (gel) = 0.41	$RRF_w = 43$  $RRF_o = 5.6$	7.68	$k_o = 1801$ ( $S_w = 0.05$ )  $k_{o,g} = 319$ ( $S_w = 0.25$ )	$k_w = 2199$ ( $S_w = 0.46$ )  $k_{w,g} = 51$ ( $S_w = 0.52$ )
50% gelant in emulsion, $S_w$ (gel) = 0.57	$RRF_w = 350$  $RRF_o = 9.0$	39	$k_o = 1894$ ( $S_w = 0.09$ )  $k_{o,g} = 209$ ( $S_w = 0.34$ )	$k_w = 2317$ ( $S_w = 0.50$ )  $k_{w,g} = 6.6$ ( $S_w = 0.65$ )
100% gelant (no emulsion), $S_w$ (gel) = 1	$RRF_w = 1000$  $RRF_o = 16$	62	$k_o = 2136$ ( $S_w = 0.21$ )  $k_{o,g} = 132$ ( $S_w = 0.43$ )	$k_w = 2618$ ( $S_w = 0.60$ )  $k_{w,g} = 2.7$ ( $S_w = 0.63$ )

With the water-wet core the permeability reduction was much stronger (figures 8-9 and table 3). A emulsion with 25% gelant gave  $RRFW = 214$  which is almost 100 times more than a 25% emulsion in fractional wet cores. The emulsion system does however give a pronounced DPR effect also in water wet media.

5

**Table 3.** Summary on experimental result using emulsified gelant and a water-wet core.

Gelant content in the emulsions and saturation after plament ( $S_w$ (gel))	Residual resistance factors	Selectivity $RR_w/RRF_o$	Endpoint permeability for oil/endpoint saturation before and after gel treatment	Endpoint permeability for brine/endpoint saturation before and after gel treatment
25% emulsion, $S_w$ (gel) = 0.58	$RRF_w = 214$ $RRF_o = 18$	12	$k_o = 2548$ ( $S_w = 0.21$ )  $k_{o,g} = 142$ ( $S_w = 0.34$ )	$k_w = 1539$ ( $S_w = 0.77$ )  $k_{w,g} = 7.2$ ( $S_w = 0.77$ )

10

Table 4

Exp. 1: Pore volume = 42.79 ml, fractional wet

Inj. S <sub>w</sub>	Oil prod.	Saturation	DP	Perm.	Rate
	21.9	0.47	0.8	1223	0.5
	23.4	0.51	1.28	1529	1
	24.5	0.53	2.1	1864	2
	24.6	0.53	4.1	1910	4
	24.9	0.54	6.2	1894	6
Inj. oil	S <sub>w</sub> prod.	Saturation	DP	Perm.	Rate
	16	0.21	0.93	1210	0.5
	18.1	0.16	1.52	1481	1
	20	0.11	2.92	1542	2
	20.5	0.10	5.49	1640	4
	20.8	0.10	8.12	1663	6
Inj. S <sub>w</sub>	Oil prod.	Saturation	DP	Perm.	Rate
	19.8	0.52	1.25	1566	1
	20.9	0.54	2.1	1864	2
	21.2	0.55	4.45	1760	4
	21.55	0.56	6.55	1793	6
Gelant	Prod.		DP		Rate
	0		2.06		0.23
Inj. S <sub>w</sub>	Oil prod.	Saturation	DP	Perm.	Rate
	1.7	0.62	35	0.06	0.001
Inj. oil	S <sub>w</sub> prod.	Saturation	DP	Perm.	Rate
	3.5	0.49	6.27	0.72	0.002
	6.3	0.43	11.3	0.80	0.004
	8	0.39	13.4	1.68	0.01
	9	0.37	20	2.25	0.02
	10.4	0.33	20.5	4.39	0.04
	11.6	0.31	22.5	8.00	0.08
	12.1	0.29	22	10.23	0.1
	12.9	0.27	24.6	13.73	0.15
	13.5	0.26	24.5	18.38	0.2
	14.9	0.23	17.6	38.37	0.3
Inj. S <sub>w</sub>	Oil prod.	Saturation	DP	Perm.	Rate
	15.1	0.54	41	0.10	0.002



**Table 5**

Exp. 2: Pore volume = 44.56 ml, fractional wet

Inj. $S_w$	Oil prod.	Saturation	DP	Perm.	Rate
	19.8	0.41	0.18	1088	0.1
	21.7	0.45	0.75	2610	1
	22.1	0.46	1.59	2462	2
	22.5	0.47	2.89	2709	4
	22.8	0.47	4.3	2731	6
Inj. Oil	$S_w$ prod.	Saturation	DP	Perm.	
	18.3	0.20	0.59	1908	0.5
	19.4	0.18	1.12	2010	1
	20.1	0.16	2.19	2056	2
	20.9	0.14	4.19	2149	4
	21.5	0.13	6.13	2203	6
Inj. $S_w$	Oil prod.	Saturation	DP	Perm.	
	16.9	0.37	0.7	1398	0.5
	17.8	0.39	1.05	1864	1
	19.4	0.43	3.33	2351	4
	20.3	0.45	4.31	2725	6
Gelant			13.2		2.3
Inj. $S_w$	Oil prod.	Saturation	DP	Perm.	
	3.2	0.52	24.9	0.39	0.005
Inj. Oil	$S_w$ prod.	Saturation	DP	Perm.	
	3.4	0.48	6.3	3.6	0.01
	4.5	0.46	9.67	7.0	0.03
	6.8	0.41	11.52	19.5	0.1
	8.7	0.36	10.98	41.0	0.2
	8.9	0.36	20.99	42.9	0.4
	10.7	0.32	15.96	112.8	0.8

Table 6

20% emulsion (2), fractional wet:

Pore volume = 40.0

Inj. $S_w$	Oil prod.	Saturation	DP	Perm.	Rate
	19.6	0.446	0.19	1030	0.1
	21.2	0.486	0.63	1554	0.5
	21.75	0.500	1.13	1732	1
	21.75	0.500	2.31	1695	2
	21.8	0.501	4.56	1717	4
	21.9	0.504	6.81	1725	6
Inj. Oil	$S_w$ prod	Saturation	DP	Perm.	Rate
	15.9	0.150	0.37	608	0.1
	18	0.097	1.04	1082	0.5
	18.5	0.085	1.88	1197	1
	18.8	0.077	3.63	1240	2
	19.3	0.065	6.87	1311	4
	19.4	0.062	10.15	1331	6
Gelant			9.56		1
Inj. $S_w$	Oil prod.	Saturation	DP	Perm.	Rate
	9.9	0.570	7.81	1.3	0.00
	10.4	0.582	9.78	2.0	0.01
	10.6	0.587	12.94	7.6	0.05
	10.7	0.590	14.4	13.6	0.1
	11.3	0.605	19.2	51.0	0.5
	11.3	0.605	27.11	72.2	1
Inj. Oil	$S_w$ prod.	Saturation	DP	Perm.	Rate
	8.2	0.443	2.3	9.8	0.01
	8.6	0.433	3.21	14.0	0.02
	10.3	0.391	3.49	32.3	0.05
	11.65	0.357	4.3	52.4	0.1
	12.3	0.341	4.49	100.3	0.2
	14.3	0.291	7.19	156.5	0.5
	16	0.248	9.27	242.8	1
	16.9	0.226	13.2	341.1	2
	16.9	0.226	23.58	381.9	4

**Table 7**

25% emulsion, fractional wet:

Pore volume = 40.0

Inj. $S_w$	Oil prod.	Saturation	DP	Perm.	Rate
	21.2	0.460	0.58	1687	0.5
	21.45	0.466	1.2	1631	1
	21.6	0.470	2.39	1638	2
	21.7	0.472	4.73	1655	4
	22.3	0.487	6.61	1776	6
Inj. Oil	$S_w$ prod.	Saturation	DP	Perm.	Rate
	12.6	0.271	0.36	625.3	0.1
	16.1	0.188	0.91	1236	0.5
	17.3	0.159	1.72	1308	1
	18	0.143	3.23	1393	2
	19.5	0.107	6.05	1488	4
	19.7	0.103	8.93	1512	6
Gelant			9.1		1
Inj. Oil	$S_w$ prod.	Saturation	DP	Perm.	Rate
	1.2	0.353	0.93	242.1	0.1
Inj. $S_w$	Oil prod.	Saturation	DP	Perm.	Rate
	8.9	0.522	2.74	35.7	0.05
	9.6	0.539	3.16	61.9	0.1
	9.6	0.539	3.53	277.3	0.5
	10.2	0.553	5.15	380.1	1
	10.5	0.560	8.45	463.3	2
	10.6	0.562	13	602.3	4
	10.7	0.565	17.44	673.5	6
Inj. Oil	$S_w$ prod.	Saturation	DP	Perm.	Rate
	13.2	0.293	1.05	214.4	0.1
	16.4	0.218	2.55	441.4	0.5
	17.5	0.192	3.72	605.1	1
	18.1	0.177	6.24	721.5	2
	18.2	0.175	10.69	842.3	4

**Table 8**

30% emulsion, fractional wet:

Pore volume = 44.4

Inj. S <sub>w</sub>	Oil prod.	Saturation	DP	Perm.	Rate
	20.7	0.427	0.55	1780	0.5
	20.75	0.428	1.1	1780	1
	21.8	0.452	1.99	1967	2
	22.2	0.461	3.67	2134	4
	22.4	0.465	5.34	2199	6
Inj. Oil	S <sub>w</sub> prod.	Saturation	DP	Perm.	Rate
	13.95	0.190	0.28	804	0.1
	16.95	0.123	0.82	1373	0.5
	16.95	0.123	1.62	1390	1
	19.5	0.065	2.76	1631	2
	20.2	0.050	5.1	1766	4
	20.2	0.050	7.5	1801	6
Gelant			7.59		1
Inj. Oil	S <sub>w</sub> prod.	Saturation	DP	Perm.	Rate
	0.4	0	1.93	117	0.1
Inj. S <sub>w</sub>	Oil prod.	Saturation	DP	Perm.	Rate
	4.9	0.406	8.28	0.5	0.00
	8.65	0.490	10	1.0	0.00
	9.3	0.505	11.03	1.8	0.01
	9.4	0.507	11.66	3.4	0.02
	9.5	0.509	13.43	7.3	0.05
	9.8	0.516	15.04	13.0	0.1
	10.2	0.525	19.11	51.2	0.5
Inj. Oil	S <sub>w</sub> prod.	Saturation	DP	Perm.	Rate
	7.2	0.402	1.97	11	0.01
	7.2	0.402	4.94	23	0.05
	7.4	0.398	5.22	43	0.1
	10.2	0.334	7.93	142	0.5
	12.3	0.287	12.92	174	1
	12.7	0.278	17.54	257	2
	13.8	0.253	28.23	319	4

**Table 9**

50% emulsion, fractional wet:

Pore volume = 44.77

Inj. S <sub>w</sub>	Oil prod.	Saturation	DP	Perm.	Rate
	20.1	0.41	0.11	1780	0.1
	22.4	0.46	0.4	2447	0.5
	23.1	0.48	0.84	2330	1
	23.4	0.48	1.7	2303	2
	23.6	0.49	3.66	2139	4
	24.14	0.50	5.08	2312	6
Inj. Oil	S <sub>w</sub> prod.	Saturation	DP	Perm.	
	15.2	0.200	0.27	834	0.1
	17.4	0.151	0.84	1340	0.5
	18.6	0.124	1.4	1608	1
	19.1	0.113	2.66	1693	2
	19.9	0.095	4.93	1826	4
	20.0	0.093	7.13	1894	6
Inj. S <sub>w</sub>	Oil prod.	Saturation	DP	Perm.	
	14.3	0.413	0.71	1379	0.5
	15.2	0.433	1.25	1566	1
	16.7	0.466	1.96	1997	2
	16.9	0.471	3.89	2013	4
	17.1	0.475	5.65	2079	6
	17.8	0.491	5.07	2317	6
Gelant			13.3		1
Inj. S <sub>w</sub>	Oil prod.	Saturation	DP	Perm.	
	7.4	0.60	9.24	4.24	0.02
	9.4	0.65	11.8	6.64	0.04
Inj. Oil	S <sub>w</sub> prod.	Saturation	DP	Perm.	
	10.6	0.451	2.13	106	0.1
	13.9	0.377	2.85	158	0.2
	15.6	0.339	4.51	200	0.4
	15.7	0.337	6.45	209	0.6
Inj. S <sub>w</sub>	Oil prod.	Saturation	DP	Perm.	
	14.3	0.618	7.02	6.41	0.02

**Table 10**

25% emulsion, water wet:

Pore volume = 37.39

Inj. $S_w$	Oil prod.	Saturation	DP	Perm.	Rate
	29.8	0.750	0.75	1305	0.5
	29.6	0.745	1.34	1460	1
	29.8	0.750	2.65	1477	2
	30	0.756	5.39	1452	4
	30.4	0.767	7.63	1539	6
Inj. Oil	$S_w$ prod.	Saturation	DP	Perm.	Rate
	13.1	0.464	0.36	625.3	0.1
	17.4	0.349	0.68	1655	0.5
	17.8	0.338	1.28	1758	1
	20.7	0.261	2.03	2217	2
	22.1	0.223	3.68	2446	4
	22.6	0.210	5.3	2548	6
Gelant		0.584	5.61		1
Inj. Oil	$S_w$ prod.	Saturation	DP	Perm.	Rate
	2.2	0.571	2.07	108.8	0.1
Inj. $S_w$	Oil prod.	Saturation	DP	Perm.	Rate
	9.7	0.784	20.73	0.378	0.004
	10.2	0.798	23.21	0.843	0.01
Inj. Oil	$S_w$ prod.	Saturation	DP	Perm.	Rate
	6.6	0.668	3.62	6.2	0.01
	8.5	0.617	3.54	12.7	0.02
	11	0.550	4.4	25.6	0.05
	14.2	0.464	4.12	54.6	0.1
	17.1	0.387	6.53	172.4	0.5
	18.9	0.339	15.83	142.2	1
Inj. $S_w$	Oil prod.	Saturation	DP	Perm.	Rate
	17.9	0.771	27.2	7.20	0.1

**Claims :**

1. Composition for reducing water permeability more than oil permeability in a subterranean reservoir, which composition comprises an aqueous gelant emulsified in oil.  
5
2. Composition according to claim 1, wherein the gelant concentration in the emulsion is in the range up to 50 volume%, preferably above 5 volume%.
- 10 3. Composition according to claim 1-2, wherein the gelant comprises water soluble polymers, preferably polyacrylamides, polyacrylate copolymers or biopolymers.
- 15 4. Composition according to claim 1-3, wherein the polymer concentration in the gelant is present in a concentration sufficient to give a stable gel after crosslinking, usually in the concentration range of from 1000 to 50000 ppm, preferably in the concentration range of from 2000 to 10000 ppm.
- 20 5. Composition according to claim 1-4, wherein the gelant comprises one or several crosslinking agents, preferably hexamethylenetetramine and/or salicyl alcohol and/or trivalent metal ions preferably chromium or aluminium .
- 25 6. Composition according to claim 5, wherein one or several crosslinking agents is present in a concentration range of from 50-5000 ppm, preferably in a concentration range of from 100-1000 ppm.
7. Composition according to claim 1-6, wherein the emulsion is stabilised by a surfactant, preferably an oil soluble surfactant.
- 30 8. Composition according to claim 7, wherein the surfactant is present in a concentration range of from 0.05 to 10%, preferably in the range of from 0.1 to 2%.

9. Composition according to claim 1-8, wherein the emulsion breaks in 1-15 hours at a temperature of from 50-130°C.
10. Composition according to claim 1-8, wherein a gel is formed after the emulsion breaks.
11. Process for reducing the water permeability more than the oil permeability in a subterranean reservoir, wherein an aqueous gelant emulsified in oil is injected into a reservoir.
12. Process according to claim 11, wherein the gelant concentration in the emulsion is in the range up to 50 volume%, preferably above 5-volume%
13. Process according to claim 11-12, wherein the gelant emulsified in oil comprises water soluble polymers, preferably polyacrylamides, polyacrylate copolymers or biopolymers.
14. Process according to claim 11-13, wherein the polymer concentration in the gelant emulsified in oil is present in the concentration sufficient to give a stable gel after crosslinking, usually in the concentration range of from 1000 to 50000 ppm, preferably in the concentration range of from 2000 to 10000 ppm.
15. Process according to claim 11-14, wherein the gelant comprises one or several crosslinking agents, preferably hexamethylenetetramine and/or salicyl alcohol, and/or trivalent metal ions preferably chromium or aluminium.
16. Process according to claim 11-15, wherein one or several crosslinking agents are present in the range of from 50 – 5000 ppm, preferably in the concentration range of from 100-1000 ppm.
17. Process according to claim 11-16, wherein the emulsion is stabilised by a surfactant, preferably an oil soluble surfactant.



18. Process according to claim 17, wherein the surfactant is present in a concentration range of from 0.05 to 10%, preferably in the range of from 0.1 to 2%.

19. Process according to claim 11-18, wherein the emulsion breaks in 1-15  
5 hours at a temperature of 50 - 130°C.

20. Process according to claim 11-19, wherein a gel is formed before the emulsion breaks.

10 21. Use of a composition comprising an aqueous gelant emulsified in oil for reducing the water permeability more than the oil permeability in subterranean reservoir.

22. Use according to claim 21, wherein the gelant concentration in the emul-  
15 sion is in the range up to 50 volume%, preferably in the range of 5-50%.

23. Use according to claim 21-22, wherein the gelant emulsified in oil comprises water soluble polymers, preferably polyacrylamides, polyacrylate copolymers or biopolymers.

20 24. Use according to claim 21-23, wherein the polymer concentration in the gelant emulsified in oil is present in the concentration range of from 1000 to 50000 ppm, preferably in the concentration range of from 2000 to 10000 ppm.

25 25. Use according to claim 21-24, wherein the gelant comprises one or several crosslinking agents, preferably hexamethylenetetramine and/or salicyl alcohol, and/or trivalent metal ions preferably chromium or aluminium.

26. Use according to claim 21-25, wherein one or several crosslinking agents  
30 are present in the range of from 50 - 5000 ppm, preferably in the concentration range of from 100-1000 ppm.

27. Use according to claim 21-27, wherein the emulsion is stabilised by a surfactant, preferably an oil soluble surfactant.

28. Use according to claim 27, wherein the surfactant is present in a concentration range of from 0.05 to 10%, preferably in the range of from 0.1 to 2%.

29. Use according to claim 21-28, wherein the emulsion breaks in 1-15 hours  
s at a temperature of 50-130°C.

30. Use according to claim 21-29, wherein a gel is formed after the emulsion breaks.

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(54) Title: EMULSIFIED GELANT

(57) Abstract: Composition and a process for reducing the water permeability more than the oil permeability using a gelant emulsified in oil. The use of a composition comprising an aqueous gelant emulsified in oil is also included in the present invention.

WO 01/21726 A1

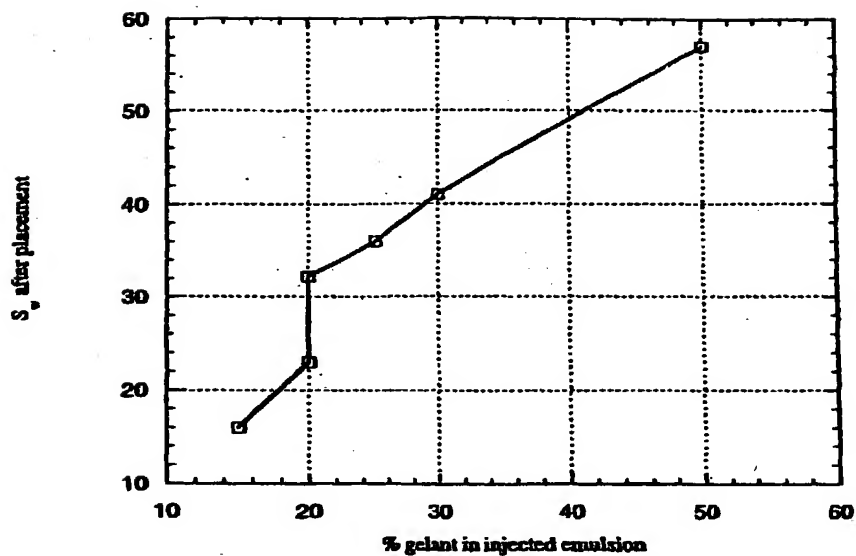


Figure 1. Saturation after placement in a fractional wet core as a function of % gelant in the injected emulsion.

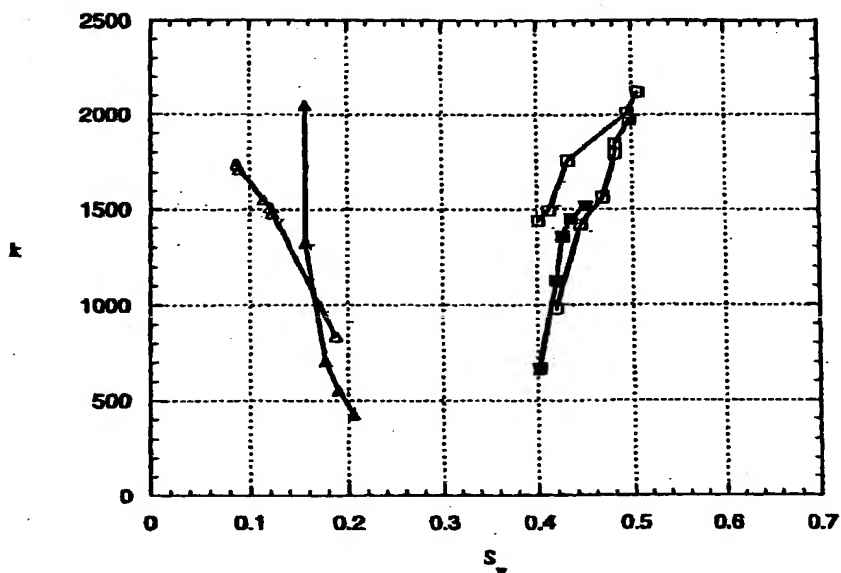


Figure 2. 15% gelant in the emulsion, fractional wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).

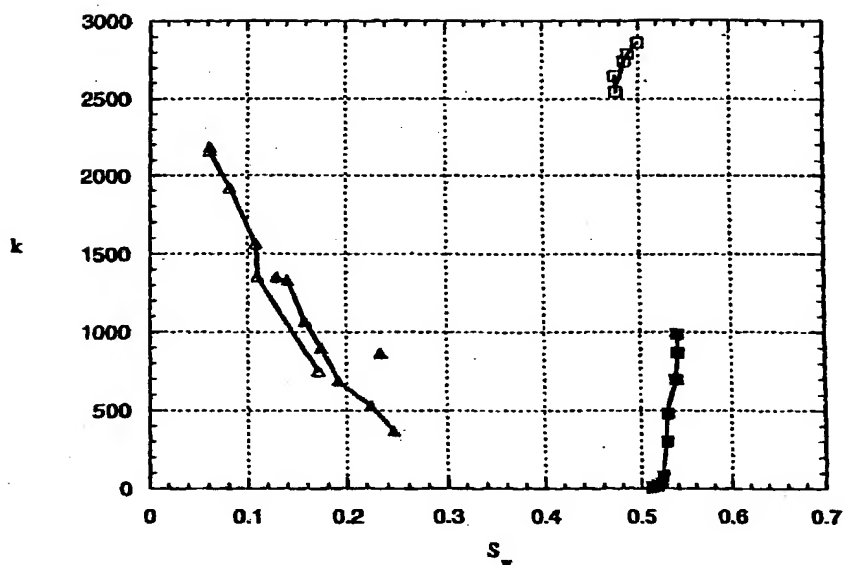


Figure 3. 20% gelant in the emulsion, fractional wet (run 1). Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).

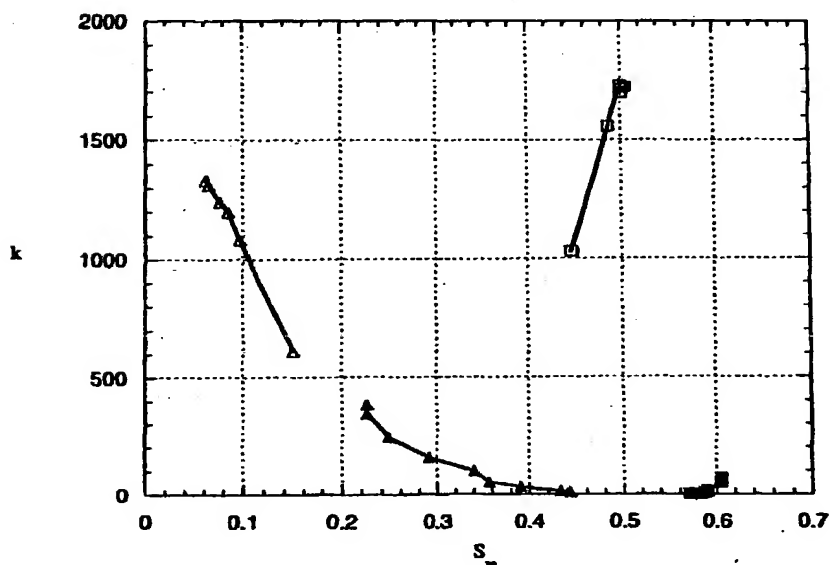


Figure 4. 20% gelant in the emulsion (run 2), fractional wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).

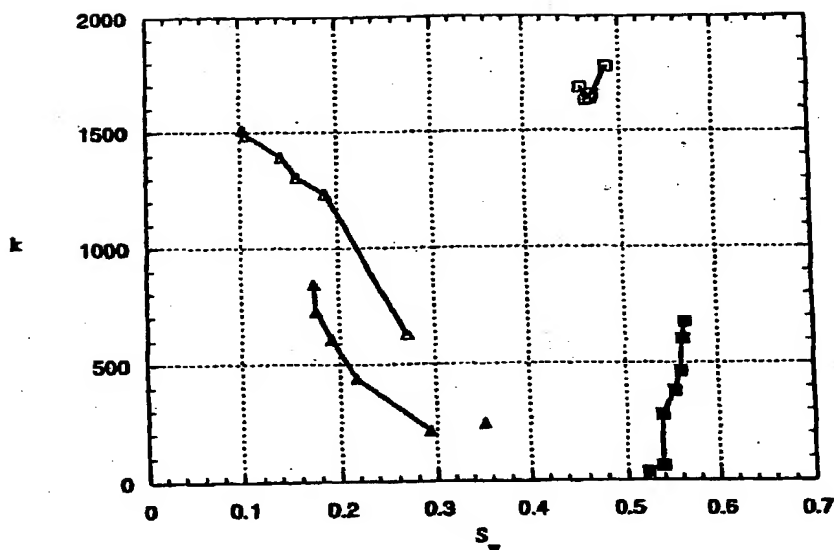


Figure 5. 25% gelant in the emulsion, fractional wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).

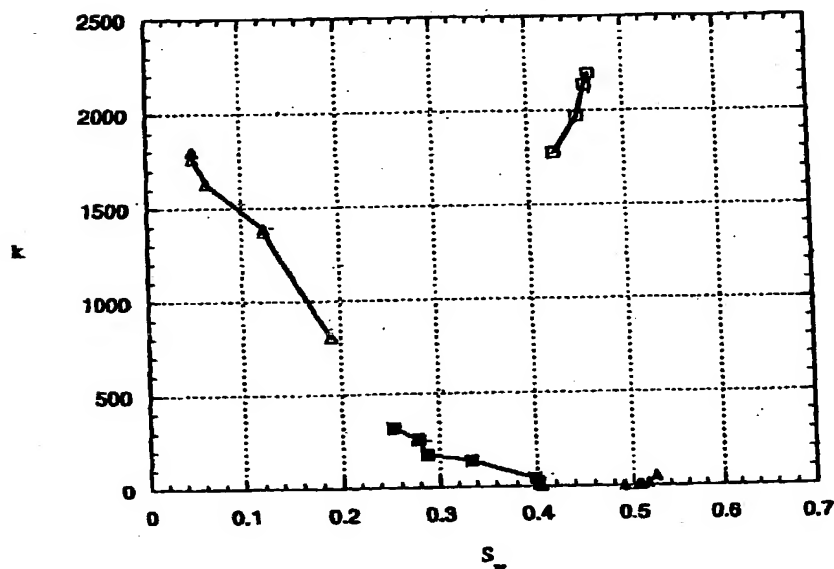


Figure 6. 30% gelant in the emulsion, fractional wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).

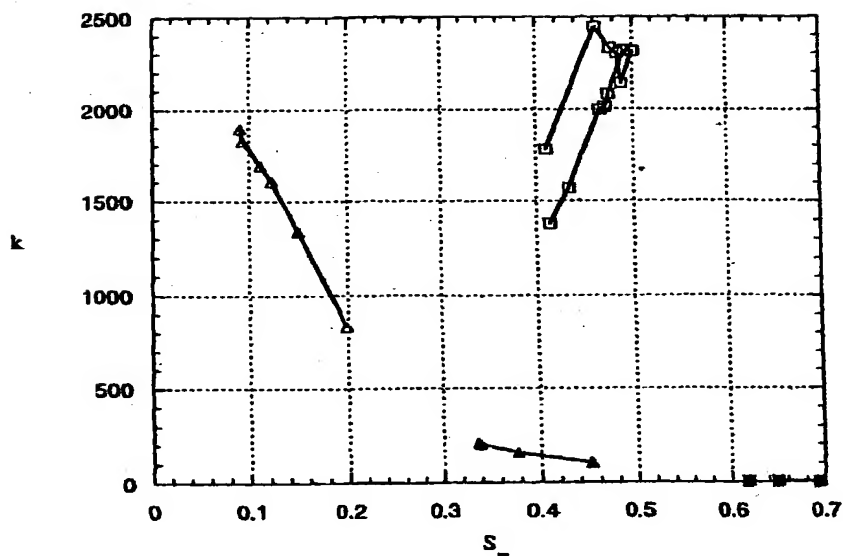


Figure 7. 50% gelant in the emulsion, fractional wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).

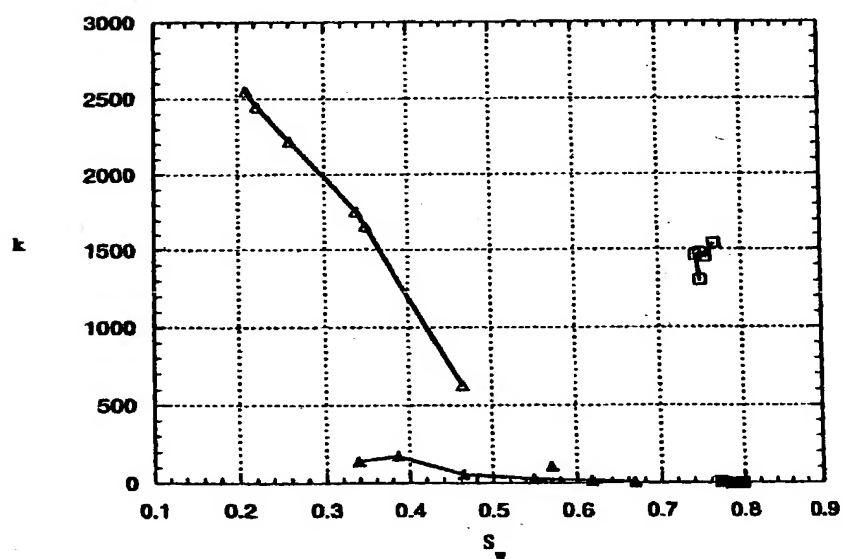


Figure 8. 25% gelant in the emulsion, water wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).

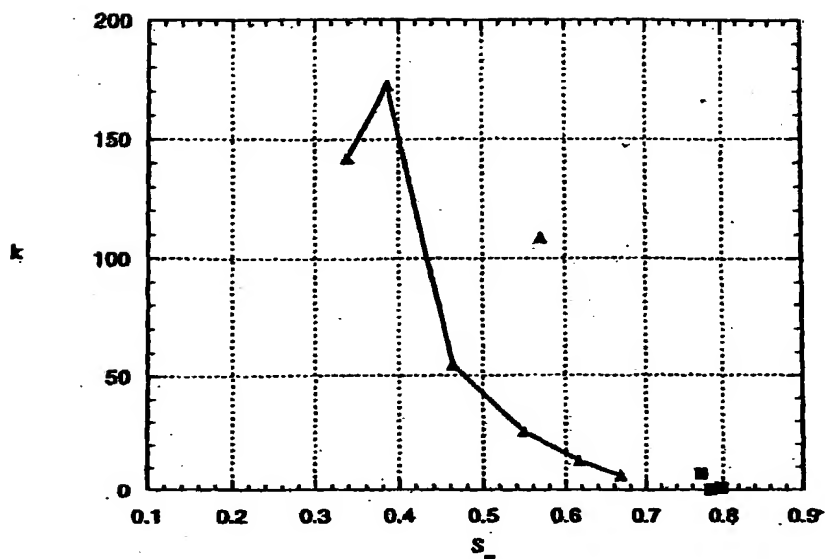


Figure 9. 25% gelant in the emulsion, water wet. Relative permeability curves after gel treatment for oil (triangles) and water (squares).

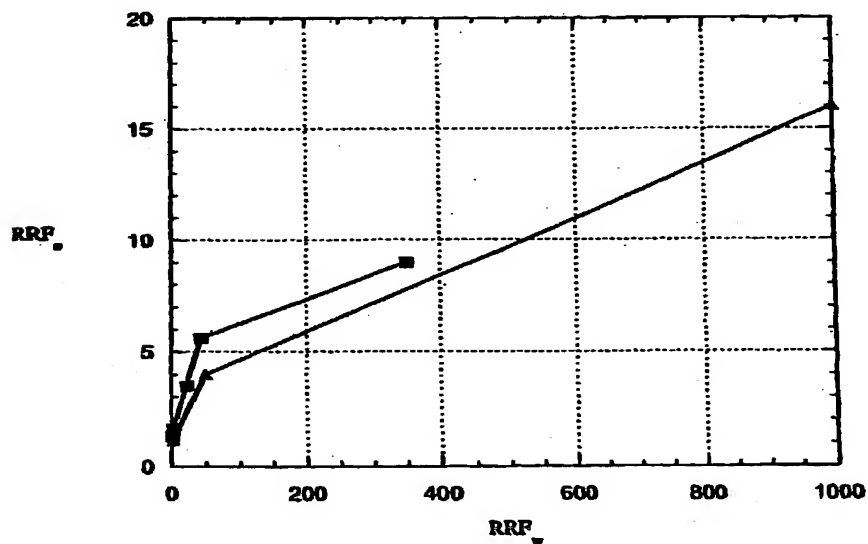


Figure 10. Residual resistance factor for oil as a function of residual resistance factor of water after gel treatment of fractional wet cores. Squares denote emulsified gel and triangles denote coinjection (data taken from 1997 Reserve gel report).



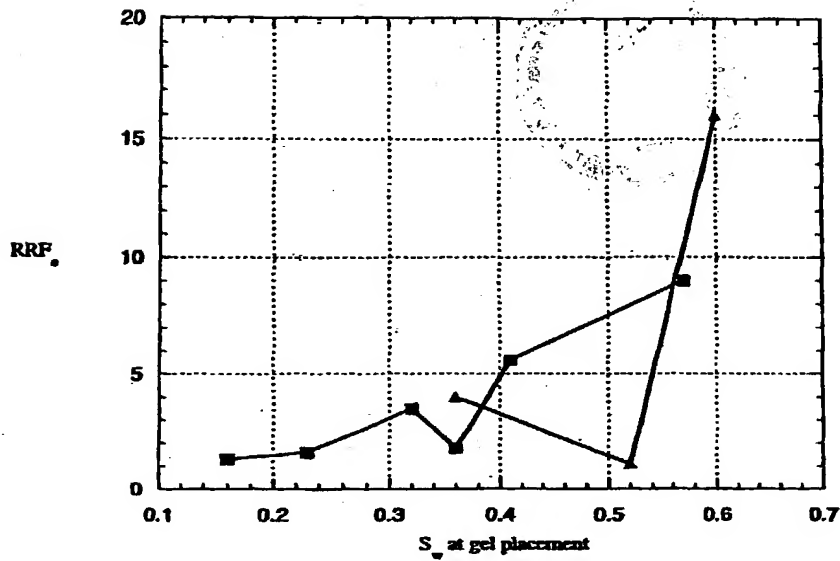


Figure 11. Residual resistance factor of oil as a function of saturation at gel placement. Squares denote emulsified gel and triangles denote coinjection (data taken from 1997 Reserve gel report).

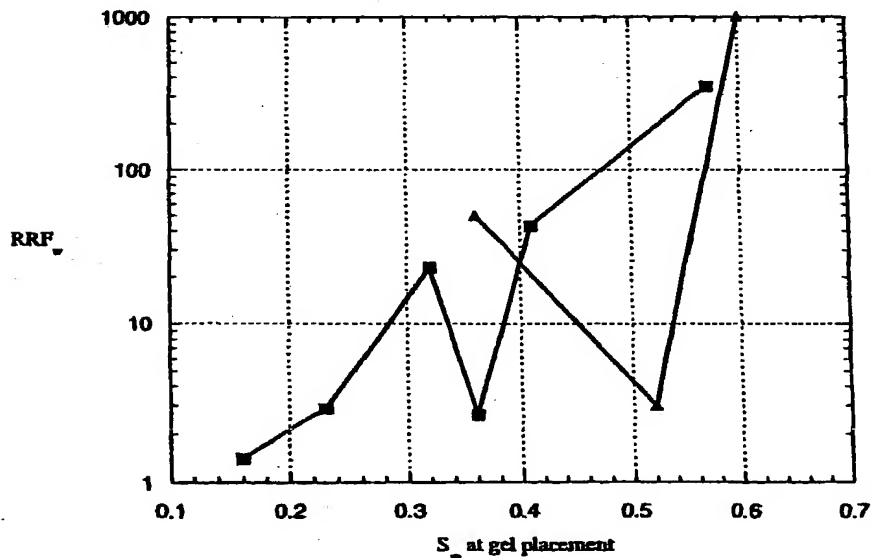


Figure 12. Residual resistance factor of water as a function of saturation at gel placement. Squares denote emulsified gel and triangles denote coinjection (data taken from 1997 Reserve gel report).

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## DECLARATION AND POWER OF ATTORNEY FOR U.S. PATENT APPLICATION

( ) Original ( ) Supplemental ( ) Substitute (X) PCT ( ) DESIGN

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Title: EMULSIFIED GELANT

of which is described and claimed in:

- ( ) the attached specification, or  
 ( ) the specification in application Serial No. \_\_\_\_\_, filed \_\_\_\_\_, and with amendments through \_\_\_\_\_, or  
 (X) the specification in International Application No. PCT/NO00/00302, filed September 15, 2000, and as amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the content of the above-identified specification, including the claims, as amended by any amendment(s) referred to above.

I acknowledge my duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim priority benefits under Title 35, United States Code, §119 (and §172 if this application is for a Design) of any application(s) for patent or inventor's certificate listed below and have also identified below any application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:


COUNTRY	APPLICATION NO.	DATE OF FILING	PRIORITY CLAIMED
Norway	1999 4692	September 24, 1999	Yes

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

APPLICATION SERIAL NO.	U.S. FILING DATE	STATUS: PATENTED, PENDING, ABANDONED

And I hereby appoint Michael R. Davis, Reg. No. 25,134; Matthew M. Jacob, Reg. No. 25,154; Warren M. Cheek, Jr., Reg. No. 33,367; Nils Pedersen, Reg. No. 33,145; Charles R. Watts, Reg. No. 33,142; and Michael S. Huppert, Reg. No. 40,268, who together constitute the firm of WENDEROTH, LIND & PONACK, L.L.P., as well as any other attorneys and agents associated with Customer No. 000513, to prosecute this application and to transact all business in the U.S. Patent and Trademark Office connected therewith.

I hereby authorize the U.S. attorneys and agents named herein to accept and follow instructions from Bryn & Aarflo AS as to any action to be taken in the U.S. Patent and Trademark Office regarding this application without direct communication between the U.S. attorneys and myself. In the event of a change in the persons from whom instructions may be taken, the U.S. attorneys named herein will be so notified by me.

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I further declare that all statements made herein of my own knowledge are true, and that all statements on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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